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BASELINE ENVIRONMENTAL DATA COLLECTION FOR A NEW HOG RESEARCH/PRODUCTION FACILITY

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Baseline Environmental Data Collection for a New Hog Research / Production Facility

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Baseline Environmental Data Collection for a New Hog Research / Production Facility

Project Director
Dr. Ernie Barber
Department of Agricultural and Bioresource Engineering
College of Engineering
57 Campus Drive
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 5A9

Co-investigators
Philip Willson[2]
Terry Fonstad[1]
Charles Maulé[1]
Stephan Lemay[3]
Harvey Filson[4]

Project Engineers
Laura Ingram[1]
Sherry Perih[1]
Denise Meier[1]

Abstract

Potential environmental impacts associated with intensive livestock operations are recognized as a major factor limiting the establishment of these operations in Saskatchewan. This project involved the collection of environmental data for "pre-operation" analyses of the area surrounding a commercial pig production facility. These data will help future studies determine true environmental impacts of pig production facilities on the surrounding environment. Baseline data for air, surface water, ground water, and soil quality at PSC Elstow are presented and discussed in this report. Information also includes data collected during the beginning of operations at the barn. Information regarding the background quality of environmental parameters is important to establish for an environmental impact study, because indicating parameters for pollution may already be present in the environment. It is now possible to consider PSC Elstow a fully characterized site, unique in the ability to support studies of true environmental impact of intensive swine operations.

1. Dept. of Ag and Bio Eng. College of Engineering, 57 Campus Drive, University of Saskatchewan, S7H 5A9
2. Veterinary Infectious Disease Organization, 120 Veterinary Road, Saskatoon, SK S7N 5E3
3. Prairie Farm Rehabilitation Administration, National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon SK S7N H5
4. Prairie Swine Centre Inc., 2105 – 8th Street East Saskatoon SK S7H 5N9

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Executive Summary

The main objective of this project was to collect environmental data prior to and immediately following construction of a new hog production facility. This includes collection of pre- and post-construction odor samples of the surrounding area within 2.4 km of the proposed site and neighbouring farmyards, as well as the collection of groundwater, surface water and soil quality data from the barn site and surrounding area. Other sampling regimes to help classify air quality were included later in the project.

The project site is the PSC Elstow Research Farm Inc. Site establishment at the PSC barn began in May of 1999. This began with the selection of the odor sampling grid surrounding the barn. Odor sampling has occurred for a sampling period of two years from May, 1999 to February, 2001. An additional sampling set was collected in July, 2001.

Deep groundwater piezometers were installed at Elstow over the fall and winter of 1999/2000. Monitoring and sampling of piezometers commenced in March of 2000. Well water samples were obtained in May 2000 and May 2001. Surface water samples were also collected, both from the watersheds established on the land for manure application and from existing water bodies. Shallow groundwater piezometers were installed at the watersheds in fall of 2000 and have been sampled periodically.

Baseline soil data collection on the barn site was completed in the fall of 1999 and spring of 2001. Soil samples to establish background quality on the land for manure application were collected at the watersheds in October of 1999 and October of 2000.

Additional air sampling to determine the loading rates of airborne bacteria on the air surrounding the hog barn was initiated in August of 2000. Sampling to determine dust loading rates of the air was included in March of 2001.

Written agreements regarding shared data and protocols were obtained with organizations in both Alberta and Manitoba. In Alberta, John Feddes at the University of Alberta and Richard Coleman at the Alberta Research Council have become involved. Sylvio Tessier of Manitoba Agriculture has also indicated support.

1.0 Introduction and Background

The province of Saskatchewan has set a goal to dramatically increase pork production in the province. Meeting this goal will depend somewhat upon removing barriers to expansion. This includes the uncertainty regarding environmental impacts of new facilities upon the surrounding area. Once the true environmental impacts of an intensive hog facility are determined, it will be easier for the hog industry to address environmental concerns.

Saskatchewan pork producers are "pro-active" in their attempts to reduce environmental impacts on neighbors. Currently, the hog industry is somewhat left wanting for hard, solid facts upon which to base their decisions. Scientific data collection and analysis on the true air, soil, and water impacts of a pork production facility, from pre-construction on, will make it easier to address concerns regarding environmental impacts.

This project involved the collection of environmental data for pre-operation analyses of the air, soil, and water quality in the area surrounding a new pig production facility. Few studies have been performed that determine the true environmental impacts hog production facilities have on their surrounding environment, therefore this study creates a valuable baseline for future studies and research.

The site studied is PSC Elstow Research Farm Inc., a 600 sow farrow-to-finish research facility. The facility is designed and constructed along commercial standards in order to provide a research facility replicating, as closely as possible, today's commercial production conditions. This site was ideal for this project for a number of reasons. First, it provided the opportunity to coordinate efforts with currently funded studies. Second, it ensured information obtained through this study would be of direct use to future studies. Finally, it allowed the timeline, specifically, the length of time necessary prior to the commencement of construction, required for this project to be satisfactorily met.

In order to establish a relevant environmental baseline for the PSC Elstow site, it was necessary to determine the aspects of the environment quality not necessarily just of scientific interest, but of concern to the surrounding residents. It was established water quality, both of surface and groundwater, would need to be included along with basic soil quality and ambient air quality.

The effect of the livestock operation on the local water supply will depend on the characteristics of local ground and surface waters (Jackson et.al., 1995). Once contamination has occurred, it is difficult, if not impossible, to determine the portion of the constituent in question that is due to contamination. For example, once nitrogen is in a water soluable form, its source cannot be easily distinguished. Therefore, it is important to acquire dependable baseline values for water quality in order to establish the true effects of a livestock operation on the environment. This is especially true in a rural setting, where the possibility for contamination exists from many sources.

Most of the complaints associated with intensive swine production facilities are due to odor. Dispersion modeling as well as sampling near established facilities suggests that odor concentration quickly decreases as distance from the facility increases. Unfortunately, it is difficult to confirm at what distance the odor becomes undetectable because, often, the natural odor trends of the area are not known (Zhou et.al., 2000).

Apart from some odor sampling and modeling, not much attention has focused on quantifying the air outside an intensive swine facility. Inside the barn, the bacteria present in the settled dust have been described (Martin *et.al.*, 1996), along with the bacteria present on the airborne dust (Andersson *et.al.*, 1999). It has been established that at high concentrations, the dust present in swine barns has an adverse effect on lung function (Dosman *et. al.*, 2000). Endotoxin is also a recognized component that is present in the atmosphere inside livestock buildings. Many adverse effects of endotoxin on human health have been demonstrated. Threshold limit values for endotoxin exposure have been recommended in the swine industry at 5 ng/m^3 (Donham *et al.*, 1989), which is equivalent to approximately 50 Endotoxin Units (EU)/m^3. Levels of endotoxin approximately twice this concentration are not uncommon in swine confinement facilities (Dosman *et al.*, 2000). An additional component of dust in confinement livestock buildings is DNA. Immunostimulatory DNA sequences (ISS) including sequences that occur naturally in bacterial DNA have been shown to induce cytokine production. Information on the airborne constituents present in the barn helps to identify what to look for in what concentrations outside of the facility. There is very little information about the bacteria and endotoxin in the air around swine barns, especially during the beginning of operations.

Although animal manure is known to contain nutrients that enhance crop yields, there is little documented knowledge about the environmental impact on ecosystems of the semi-arid to sub-humid prairies. Excess amounts with time could result in soil degradation, pollution of surface groundwater, potential health problems for wildlife, upset ecosystem stability of wetland and potential health problems for animals and humans.

2.0 Objectives

The overall objective of this project is to collect environmental data prior to construction of a hog production facility. This objective was met by:

- Determining pre- and early post-construction air quality of the surrounding area within 2.4 km of the proposed site and at neighbouring farmyards. Seasonal, wind, and temperature conditions were considered.
- Establishing current groundwater quality at the barn sites, earthen manure storages, and land slated for manure application.
- Determining current well water quality in the area surrounding the barn facility.
- Collecting surface water quality data around the barns, earthen manure storages, and lands for manure application.
- Collecting soil quality data prior to pig production or manure application.

3.0 Changes from original proposal

3.1 Inclusion of a second site

The original project agreement called for baseline monitoring to be performed at a second site. Inclusion of a second site required the procurement of additional funding, which was unsuccessfully sought. This, along with the lack of availability of a suitable monitoring site, made the inclusion of a second site unfeasible for this project.

To ensure that the second site would provide the most beneficial data for the project, the following minimum criteria were set:

- The commercial facility should be a farrow-to-finish, similar to the PSC Elstow Research Farm Inc., to ensure similar data collection and analysis.
- Ability to collect one year of data prior to construction to provide adequate baseline data.
- Possibility of participation in the ADF/PFRA EMS monitoring project.

Originally, a site that met the requirements of both the EMS monitoring and Baseline project was sought. As of June 18, 1999, four potential sites were identified:

- Brightwater (near Hanley or Outlook) – Quadra Group (permitting difficulties)
- Speers Feeder Barn (near Speers) – Heartland Livestock (permitted and potentially under construction in near future. Strictly a feeder unit)
- Theodore Site (near Theodore) – Heartland Livestock/Quadra (permitted but no commitment on construction date. Over 3 hours travel one way)
- SEW project near Cadillac, Sask. – Heartland Livestock (over 3 hours travel one way. Either a breeding or nursery facility)

- Ogema or Rama SEW projects – Big Sky Farms (Over 3 hours travel one way, strictly breeding, nursery or feeder units, and Big Sky had already contributed to the EMS monitoring project)

The decision for a second site was held off in order to determine acceptability for the EMS project, which included suitable geological conditions for PFRA as well as willingness to pay approximately $10,000 for monitoring equipment. It was then determined that, due to increased system and analysis costs, another site was not viable for the EMS monitoring project (March 2000). Therefore, an EMS monitoring system would need to be installed at the second site without the aid of the EMS project. With the EMS project, PFRA had installed piezometers as an in-kind contribution. This had greatly reduced the costs of the systems. PFRA indicated willingness to continue this in-kind contribution provided the site used would contribute to their knowledge base.

At this point, a site was required that met the original requirements as well as:

- Was willing to pay for one year of analysis for EMS monitoring on top of the required material costs,
- Had geological conditions of interest to PFRA.

On April 20, 2000, a meeting with Quadra revealed the two potential sites were still possibilities: one at Brightwater, near Outlook,SK, and the second located near Theodore, SK. Based on the more convenient location, the Brightwater site was tentatively decided on as an acceptable second site. On November 17, 2000, it was learned that the local municipal government had denied a permit for the Brightwater site. The Theodore barn had been granted permits but was too far into the construction process to meet the requirements of the Baseline Project.

Difficulty in locating a second site was compounded by several factors:
1. The drastic fall in hog prices resulted in a slow down in construction.
2. This slow down in construction was more evident in farrow-to-finish operations than in SEW projects.
3. Heartland Livestock's construction plans were hampered by profitability concerns within Sask Wheat Pool.

Finally, in March 2001 the decision was made by the project team, in consultation with ADF staff, to abandon the addition of a second site.

3.2 Changes to project design

- The original proposal called for 180 odor samples and analyses per year at the PSC Elstow Research Farm Inc. A new experimental design was devised reducing the number of odor analysis at each site to 120 per year.

- The original project design included odor analysis using the Olfactometer and Aroma Scan at Alberta Research Council. The data results from the Aroma Scan, in our opinion, did not give relevant results for baseline odor. The Aroma Scan was replaced with testing for hedonic tone, which is more applicable for a baseline odor determination.

- The original design plan included installation of 10 piezometric nests (each nest consisting of piezometers at 5, 10, and 15 m). Elstow site investigation for operating permit indicated alluvial clay to a depth of 5 to 6 meters over glacial clay till to 20 to 21 meters. This is underlain by a 2 to 3 meter thick fine sand layer and then glacial clay till. This stratigraphy dictates that the fine sand layer should be monitored, therefore three nests of five piezometers at depths of 8,12,16,22, and 30 meters below depth were installed along with two additional nests with piezometers 8,12,16, and 22 meters below grade.

- Although not anticipated in the project at the time of funding, monitoring of barn tile drains was included. Standpipes were installed beside the barn to monitor liquid from tile drains in order to reveal whether or not any seepage may be occurring from the manure pits. A baseline analysis was performed on water samples collected from the drains prior to pigs populating the barn. This analysis covered the same sweep of ions as groundwater and surface water analyses. Bi-weekly monitoring was begun when pigs started to populate the barn, consisting of water level and electrical conductivity (EC) measurements. At the occurrence of a marked increase in either parameter, a more complete sampling and analysis was performed. Because of the lack of alterations, monitoring was reduced to monthly occurrences in fall 2000. This extra monitoring was performed at a very minimal cost due to sharing resources with the Baseline project.

- Airborne bacteria monitoring was begun in August, 2000 as an addition to the project that had not been included in the original project design. This portion of the project was initiated in collaboration with Dr. Phillip Willson, manager of Bacteriology Programs at the Veterinary Infectious Disease Organization (VIDO) and Adjunct Professor, Department of Microbiology and Immunology, College of Medicine, University of Saskatchewan. The objective of this monitoring is to measure and describe bacteria in the air environment around modern swine production facilities. Sampling for this project was done in conjunction with odor sampling for the Baseline project and analysis of the samples was partially funded by Sask Pork, Alberta Pork and the Canadian Pork Council Livestock Environmental Initiative. Thus, the aerobiology assessment was added at a very small cost compared to what it would have cost as an independent project. This further illustrates the advantage of nesting projects to create a collaborative research program.

- Airborne dust sampling was added to this project in the spring of 2001to compliment the air quality monitoring already performed within the project. The purpose of this monitoring was to make a preliminary determination of how the presence of a commercial hog barn affects the quality and quantity of particulate matter in the air.This monitoring was added in lieu of a second site with the approval of ADF. The project addendum referring to this sampling can be found in Appendix B.

4.0 Methodology

4.1 Air Quality

Establishing the air quality surrounding the barn facility involved three different monitoring programs. These programs were designed to establish odor quality and intensity, loading rates of airborne bacteria, and the quantity and quality of particulate matter in the air on and around the barn site before, during, and slightly after the establishment of the hog facility. Whenever possible, monitoring for each of the three components was performed concurrently.

Field sampling protocol and sample sheets are given in Appendix C.

4.1.1 Odor Monitoring and Analysis

This section of the project was designed to monitor current odor trends of the area surrounding the proposed facilities. This was achieved by collecting air samples within 2.4 km of the proposed facilities and at neighbouring farmyards.

Air sampling of the area was done based on a circular grid, with the barn site at the center (see Figure 1). The odor sampling grid consists of three collection radiuses surrounding the barn at:

- 600 m
- 1200 m
- 2400 m

Collection points on each circle are located according to directional intersections.

To ensure that data includes annual variations in weather and activity, sample times were set in February, May, August, and November each year for two years. An additional sampling set was performed in July of 2001 to coincide with a set of airborne dust monitoring. Each collection month included three sampling days to account for varying winds and temperatures. Each sampling day consisted of a collection of 8 samples from the sampling collection grid and two samples from neighboring farmyards. All sampling locations were chosen to coincide with the prevailing wind direction.

Air samples were collected in Tedlar air sampling bags filled by a vaccuum process. To get a sample, the bag was first placed in a vaccuum tight container. All air was then evacuated from the container, causing the Tedlar air sampling bag, which was open to the atmosphere, to fill with ambient air (see Figure A-1). Air samples were taken from approximately 1.6 m height. Between sampling incidents the Tedlar bags were repeatably flushed with nitrogen gas.

The samples were collected and shipped on the same day to the Alberta Research Council for analysis. For the analysis of the first two sample sets (May and August, 1999), olfactometer and Aroma Scan analyses were performed. Upon examination, it was determined that the

Aroma Scan analysis did not provide information desired for this project, so it was replaced by hedonic tone analysis beginning February 2000.

Olfactometry involves the use of the human nose as a sensor to determine odor concentration. The human nose is generally very sensitive to odors and can detect an odor compound at the part-per-billion level, which is much more sensitive than any machine. For that reason, human panels are still the most acceptable method of odor measurement, and can be used to determine both odor concentration and odor hedonic tone.

The AS'SCENT Olfactometer, which is used at the Alberta Research Council, is a dynamic dilution olfactometer that utilizes the forced choice presentation method. This machine has three sniffing ports that deliver the diluted air sample through one port and non-odorous air through the other two. The trained odor panelist then sniffs all three ports, selecting one port of the three that is different from the other two. The panelist must declare to the panel leader if the selection was a 'guess', 'detection' or 'recognition'. The panelist then sniffs the next set of three sniffing ports, one of which also contains the diluted odor sample. However, this next set presents the odor at a higher concentration (i.e. two to three times) than the first set. The panelist continues to additional sets of sniffing ports, reporting his/her selection to the panel leader in the same manner each time. This statistical approach is called "ascending concentration series" and meets all international standards of olfactometry including ASTM (United States), CEN (European Community), NVN (Netherlands), and VDI (Germany). Olfactometer results are given in terms of the detection threshold (given in odor units, OU), which is the number of dilutions required so that 50% of the population will not be able to detect any odor. For each sample the average detection level, given in odor units from each of the eight panel members, is given as the final number.

Odor hedonic tone is also measured by an 8-person trained panel using an arbitrary but common scale to rank the odor. The scale ranges from most pleasant, +5, to most unpleasant, -5, with 0 being neutral. Hedonic tone ratings are subjective, based on each panelists' personal experience and memory. The average of the numbers given by the panel members is reported as the final rating of the sample.

4.1.2 Airborne Bacteria Sampling and Analysis

As previously mentioned, this portion of the project is part of a larger project being conducted by Dr. Phillip Willson (VIDO) at different hog facilities to determine the amount of bacteria and endotoxin in the air around swine barns at defined distances.

Sampling was begun at the PSC Elstow site August of 2000. Samples were collected during August and November of 2000, and February of 2001 at the same times as odor sampling. Airborne bacteria sampling was continued after the completion of odor sampling to include sampling sets in April and July of 2001.

Sampling locations were chosen based on the same air sampling grid as used for the odor sample collection. Each sampling day consisted of the collection of five samples, at 2.4 km downwind, 600 m downwind, 60 m downwind, 600 m upwind and 0.1 m from the barn outlet.

Collection of these samples was performed using a six-stage cascade impactor. Six media plates were placed in the sampler, and a pump was used to draw air through the sampler for a specified length of time at 60 SCFH (see Photo A-2). The sampler was cleaned thoroughly with 70% ethanol solution between each sample collection. This sampling procedure allows the determination of the size of the particle carrying viable bacteria, which is important in predicting how far it may travel and where it could lodge in the lungs if inhaled. The sample procedure was repeated at each sampling location at each sampling incident for three types of selective media plates, including Blood agar, Sabouraud Dextrose agar, and Levine EMB agar plates. This provides for the determination of the general type of bacteria.

Media plates were analyzed at VIDO. Blood agar and Levine EMB agar plates were incubated at 37°C for 18 hours. Sabouraud Dextrose agar plates were incubated at 25°C for 2 days. The number of colonies formed on each plate were counted and corrected for most probable number of originating particles with viable microorganisms.

4.1.3 Airborne Dust Sampling and Analysis

The objective of this type of sampling was to determine how the presence of the barn effects the quantity and quality of particulate matter in the air by: 1) measuring the amount of particulate matter in the air both upwind and downwind of the operation during times of high and low dust loading, and 2) analyzing the dust retrieved for endotoxin and DNA concentrations.

At least 5 mg of dust was required to complete the desired analyses. In order to retrieve that amount of dust from ambient air, it was necessary to perform high volume sampling. A total suspended solids high volume ambient air sampler from Andersen Instruments was employed. This system involves a vacuum pump capable of drawing ambient air through a filter at a rate between 1.13 and 1.7 cubic metres per minute. The sampling assembly is housed in a small shelter to protect the filter from interference caused by precipitation or debris (see Figure 2 and Photo A-3). Sampling was performed prior to spring seeding, during spring seeding, and during the summer. Each sampling period consisted of three sample sets, which included sampling 2400 m upwind, 600 m downwind and at a barn outlet. A standard sampling time of approximately 24 hours was used.

Total dust mass was determined for each sampling incident by carefully weighing each filter both before and after sample collection. This mass was then used in conjunction with flow rate measurements to determine loading rates. Procedures for dust extraction and endotoxin assay can be found in Appendix C.

To assist in the interpretation of all air sample data, a meteorological station (see Photo A-4) was assembled west of the barn in conjunction with another project being conducted by Dr. Maule. The weather station provides continuous data on wind direction, wind speed, air temperature, and relative humidity, solar radiation, precipitation and soil temperature.

4.2 Groundwater Quality

Groundwater quality in the area surrounding PSC Elstow was established by monitoring both deep and shallow piezometers installed on the barn site and the land surrounding the barn site, as well as monitoring of private water wells in the area.

4.2.1 Deep Piezometer Installation and Monitoring

The installation of the deep piezometers was completed in March 2000 by the Prairie Farm Rehabilitation Administration (PFRA). The drill rig obtained 76-mm diameter cores with 80-mm brass retainer tubes. Cores from the holes were saved for analysis. The general lithology of the formations encountered was described during drilling (see Appendix D: PFRA Drill Logs). Standpipe piezometers were installed in the holes using 50.8 mm PVC pipe. After the pipe was in place, the hole was carefully backfilled with sand to the top of the screen. A layer of the till that was removed from the hole was then tamped into place, followed by a bentonite seal. Till was used to fill the hole to within 0.5-m of the surface then another bentonite seal was placed at the soil surface.

Three nests of five piezometers at depths of 8, 12, 16, 22, 30 meters below depth were installed. The nests are approximately 400 meters apart. Two additional nests were installed to create two triangles with side dimensions of approximately 900 m. These nests have piezometers at depths of approximately 8, 12, 16, and 22 meters below grade (see Table 1). Figure 3 shows the location of the piezometer nests relative to the barn site.

The initial site investigation for the Elstow operation indicated 5 to 6 m of alluvial clay over 20 to 21 m of glacial till, beneath which lies a sand layer 2 to 3 m thick. Installation of the piezometers was performed to provide a more complete geological cross-section of the area as well as the horizontal gradient or the water table. The 22-meter piezometers were installed to monitor the sandy layer for gradient and chemistry. The upper piezometers (8, 12, and 16-m) will monitor vertical gradient through the till.

The piezometer nest on the north side of the EMS will provide up-gradient measurements of any mounding of the water table within this area. An elaborate monitoring system was installed in the EMS liner to monitor any seepage that may occur. This was completed under a project managed by Professor T.A. Fonstad.

Water levels and piezometer sampling was completed in spring 2000 and spring 2001. Water levels were taken using a sounding level. Wells were then purged with a dedicated bailer. The wells were allowed to recover and samples were taken with bailers. Any preservatives required were added to bottles. All samples were kept cool until analysis.

The samples were analyzed by the Saskatchewan Research Council (SRC) Analytical Lab for basic water quality, dissolved organic carbon, ammonia, phosphorus, total organic carbon, and ortho-phosphate concentrations.

4.2.2. Shallow Piezometer Installation and Monitoring

Shallow piezometers were installed and monitored through Dr. Maule's project. These wells were placed on five specific watersheds located on land to be used for manure application (Figure 4). In October 2000, three piezometers were installed to monitor shallow groundwater in each of the 5 basins in Elstow. Only 2 piezometers were required in Basin C as a central piezometer had already been installed in this basin in the fall of 1999. In each basin, one piezometer is located in the center, at the estimated spring water level and one positioned approximately 50 m upslope or at the basin boundary.

The water in these piezometers was cleaned by frequently pumping the water out of the piezometers during the fall, winter and spring. Water levels were also recorded at these times. Samples were taken from the centre piezometer in each basin in the fall (November 20, 2000), prior to runoff in the spring (March 14, 2001) and after runoff (April 9, 2001). Since more water ponded in Basin D than in the other basins and the ponded water persisted longer, the piezometer in Basin D was not sampled until later in the spring (April 26 and May 4, 2001) when the water level began to rise.

All samples were submitted to the Environment Canada Water Quality Laboratory in Saskatoon within 24 hours of collection. Total P, OP, NO_3, NH_4 and dissolved organic C were determined using standard Environment Canada methods. Total coliforms were determined using standard methods by the Saskatchewan Research Council Laboratory within 24 hours of collection and a suite of available ions (Ca, Mg, K, Fe, Mn, B, Cu, Zn, Pb, Cd, P and S) were determined using PRS technology by Western Ag Laboratories in Saskatoon. This technology uses exchange resins to extract available ions from the water samples.

4.2.3 Well Water Collection and Analysis

Private water well sampling was performed by PFRA in spring 2000 and spring 2001. Where wells were not accessible, water samples from dugouts were obtained.

Wells were sampled by first removing and discarding three well volumes (pumping for 15-30 minutes). All filtering and preservation required was done within 15 minutes of retrieving a sample in order to prevent iron precipitation. These samples were kept cool until testing. Care was taken to sample water before a storage facility, i.e. pressure tank or cistern, as well as avoid any sampling location near a feedlot, outhouse, or septic tank in order to minimize contamination.

Dugout sampling was performed from either a dock or a boat. The collection container was first rinsed with the dugout water. The column sampler was also rinsed by immersing two or three times in the water. With silicone stopper loose, the column was lowered vertically into the dugout to 1.5m then stoppered tightly. The sampler was then quickly raised and positioned

over the container. The stopper was partially released and the column was allowed drain. The plastic sample bottle was then filled from the collection container, capped and labelled. The sample was kept cool until testing.

Analysis of these samples was also performed by SRC Analytical for constituents commonly required by PFRA for well water quality.

As a direct result of the construction of PSC Elstow, most residents now have access to Saskatoon water. Well water is now only required for outside use (i.e. animal consumption).

4.3 Surface Water Quality

Surface water in this area generally consists of runoff, and therefore is most likely to be affected by the land application of manure. Therefore, surface water quality was established by monitoring runoff on the land for manure application. This information was complimented by sampling and analysis of existing surface water bodies on the barn site and the land surrounding the barn site.

4.3.1 Runoff Monitoring

Background runoff water quality was monitored in each of the five watersheds depicted in Figure 4. This was done by analyzing the amount and quality of snowpack in the winter and runoff in the spring.

Over each winter, snow depth transects and snow water equivalents were taken to determine the amount of water stored in the snowpack and samples were taken for analysis of nutrients, coliforms and major ions. Ten snow survey points were located in each basin in 2 perpendicular transects across each basin. Although the depth and water equivalents were measured at each survey point, only one composite sample was collected from each basin for water quality analysis.

During spring melt daily runoff amounts were measured for each watershed and samples were taken for analysis of TP, OP, NO_3+NO_2, NH_4^+ and DOC. Runoff volume in the basin was determined by measuring the depth of water at the center of the basin and using a digital elevation model (created from an elevation survey of the basins) to calculate the corresponding water volume in the basin. Grab samples from the centre of the basin at mid-depth were taken as representative samples.

All samples for nutrient analysis were submitted to the Environment Canada Water Quality Laboratory in Saskatoon within 24 hours of collection. Total P, OP, NO_3, NH_4 and dissolved organic C were determined using standard Environment Canada methods. Total coliforms were determined using standard methods by the Saskatchewan Research Council Laboratory within 24 hours of collection and a suite of available ions (Ca, Mg, K, Fe, Mn, B, Cu, Zn, Pb, Cd, P and S) were determined using PRS technology by

Western Ag Laboratories in Saskatoon. This technology uses exchange resins to extract available ions from the snow and water samples.

4.3.2 Monitoring of Surface Water Bodies

Five water catchments were chosen for sampling (see Figure 5). These water bodies were chosen based on location, all were located on land slated to receive manure from the barn or on the barn site, and size, the largest possible water bodies were chosen to increase the likelihood of year-round availability.

Water samples were taken in fall, 2000 and spring, 2001. Due to the small amount of runoff and the above average temperatures, no water was available for sampling in summer, 2001.

A wide mouth container attached to the end of a pole was used for sample retrieval. Samples were taken by wading into the water and retrieving a sample from just under the water surface outside of the disturbed area. Analysis of the samples was performed by the Saskatchewan Research Council Analytical Laboratories. This included general water quality, as well as ammonia, total carbon, organic carbon, ortho-phosphate, phosphorus, and total coliforms. The inclusion of fecal coliforms was made when it was realized that one of the fields had cattle on it during the fall.

4.4 Soil Quality

Background soil quality was established by sampling both on the barn site and on the surrounding land. The data from the analysis of these samples was used along with field observations to determine the soil type, chemistry and fertility. Sampling done on the land for manure application was completed through Dr. Maule's project.

Soil cores were taken on the barn site during the fall of 1999 and the spring of 2000. Cores were taken at a position on the barn site where construction would create minimal disturbance and not compromise accessibility in the future (see Figure 6). Six cores were taken to 3 m depth. Samples were taken at 0 to 15 cm depth, 15 to 30 cm depth, and each 30 cm interval below that. Each core set was subsampled for moisture analysis immediately upon return to the lab and was then frozen.

Soil analysis was completed by Environmental Test Laboratories (ETL). The remainder of the soil collected was air dried and stored for future use. Analysis of samples collected through Dr. Maule's project will be performed at the end of that project to reduce operator and instrument error.

Soil analysis to determine geotechnical characteristics was done on cores taken by PFRA during piezometer installation. Core sample was taken from the deepest hole in each piezometer nest using Shelby tubes. Analysis was completed in the PFRA lab in Regina. The

soil was extruded from the brass liners and stored in glass mason jars prior to analysis. All samples were tested to determine gravimetric moisture contents. Analysis on selected samples included wet bulk density, atterburg limits, grain size distribution, and hydraulic conductivity.

4.5 Tile Drain Monitoring

Drains were installed beside the barn to monitor any seepage that may be occurring from the manure pits. A baseline analysis was performed on water samples collected from the drains prior to pigs populating the barn. This analysis was identical to the groundwater analyses described previously. Bi-weekly monitoring, consisting of water level and electrical conductivity (EC) determination, was begun when pigs started to populate the barn. If any marked increase was noted in the measured parameters, a more complete sampling and analysis was performed.

5.0 Discussion of Results

5.1 Ambient Air Quality

5.1.1 Odor

Olfactometer results, with the exception of a few outliers, seem to stay fairly consistently within the range of 10 to 20 odor units, regardless of time or position (see Figure 7). Samples taken from barn outlets or manure storage surfaces can be greater than 1000 OU. The highest odor threshold values were measured for the August 16, 1999 samples. Values of 40 OU and 35 OU were measured for the 2400 m downwind and the 1200 m upwind positions respectively. Values obtained for samples from other positions that day also seem to be slightly higher than average, indicating that the higher values could be due to sampling or measurement error. Population of the barn was begun on April 3, 2000, with filling of the manure storage beginning May 8 to May 15. These incidents seem to have no measurable effect on the odor concentrations of the ambient air.

Averaging the results of olfactometer analyses according to sampling location and placing them on the air sampling grid, it can be noted that no area seems to have returned higher dilution factor results: there does not seem to be any particular odor source in the area (Figure 8). One position shows a value of 40 OU, which was measured August 16, 1999. Samples taken on this date are discussed previously. Only data taken prior to barn population is included on this figure.

Hedonic tone results, shown in Figure 9 also seem to be unaffected by barn population. No obvious trends are observed, other than that the majority of the samples seem to be considered neutral to slightly unpleasant.

Using this method of sample collection and analysis, changes in odor due to the barn could not be detected.

5.1.2 Airborne Bacteria

Table 2 gives a summary of the results from airborne bacteria sampling. This sampling was initiated after population of the barn was begun, and is therefore considered to be representative of early start-up conditions. Upwind samples are taken to represent background levels. Totals represent the sum of bacteria on all stages. Respirable numbers do not include stage 1.

Twenty-six colony forms of bacteria and fungi recovered on tryptic soy agar with 5% sheep blood exposed in stage 3 (aerodynamic particle size of 3.3 to 4.7 u m) at 0.1 m from the barn air outlet were detected. The Saskatoon District Health, Department of Laboratory Medicine determined the characteristics of these microorganisms (Table 12). Some of the isolates are associated with human disease, but aerosols are not the usual mode of transmission of these organisms in the "normal population". None of the microorganisms that were identified were clearly pathogenic for people and no *Salmonella* species were detected.

Our experimental design allowed us to examine effects of distance from the barn, month during which sampling occurred and replicate sample. Not surprisingly, the concentration of total bacteria was greatest at the barn outlet (Figure 11) and the concentration of airborne bacteria at this location did not change with the month during which sampling occurred. As shown in Figure 12, the month during which sampling occurred had a significant ($p = 0.0005$) effect on bacterial concentration at the other locations.

However, the concentration of bacteria in the air returned to fresh air levels within a short distance (Figure 10). Total bacteria concentrations at all of the other locations, including as near as 60 m down wind from the barn, were not significantly different from fresh air sampled 600 m upwind from the barn (within a sampling month). There was no significant effect of replication.

As shown by the description of the type of organisms recovered (Table 12), very few enteric bacteria were present in the airborne dust leaving the intensive livestock confinement facility. None of the colonies that grew on the EMB medium were Salmonella species, which is not surprising since there was no Salmonella disease among the pigs during the sampling period. We did not detect an effect of sampling month on the concentration of bacteria that formed colonies on EMB medium. Similar to the dispersion pattern that was noted for total bacteria, there was a significant effect of sampling location ($P<0.0001$) with higher levels only at the barn air outlet.

Consistently more colonies were detected on the medium for isolation of fungi (Saubaraud's Dextrose) than on the EMB medium, but fewer than on the completely non-selective medium (TSA with Sheep's blood). Hence we were able to detect significant effects both of season and of distance. Greater concentrations were detected during harvest (August) than during Fall or Winter.

As we found for the other microorganisms, fungi were in greatest concentration at the barn outlet; however the season had a dramatic effect on the airborne concentration of this type of microorganism.

5.1.3 Airborne Dust

Airborne dust sampling was also initiated after barn population. Figure 13 shows that loading rates of the dust are variable, especially at the 0.1m from outlet position. Loading rates at the 600m downwind position are as low or lower than background rates (2.4 km upwind position).

5.2 Groundwater Quality

5.2.1 Deep Piezometers

Analysis of the water levels in the piezometers indicates the gradient in the upper till is downward. The change in water levels with time indicates the deep piezometers in the clay and till are still recovering. The upper water table is phreatic, found at 2 to 12 m below ground surface. The water table slopes downward to the south-west.

Groundwater samples obtained from deep piezometers indicate poor quality water. Results of the groundwater analysis are compared to Canadian Environmental Quality Guidelines for drinking water (see Table 3) in Figure 14. In nest A, all pipes exceed values for, sulphate, total hardness, and specific conductivity, with the exception of C-27, which falls within guidelines for all limits. C-1 also exceeds guidelines for sodium concentrations. All pipes in nest C indicate excess sodium, sulphate, total hardness and specific conductivity. Chloride levels for this nest are also quite high, with C-42 exceeding standards. Results from nests D, E, and F also all exceed values for sodium, sulphate, hardness and specific conductivity, except for C-54, which falls within all guidelines. C-51 also exceed chloride recommendations. Nest B seems to have the cleanest water, with specific conductivity and hardness values exceeded for C-36 and C-37, and only specific conductivity too high for C-38. C-35 is within all guidelines. It should be noted that all guidelines exceeded in these water analyses are considered aesthetic objectives. The acceptability of hardness values depends on the user, but generally hardness values greater than 500 mg/L are considered unacceptable.

5.2.2 Shallow Piezometers

Shallow piezometers installed in the watershed on the land for manure application indicate that the depth to the water table ranges from 1.7 to 4.7 m. Water level data for the centre piezometers plotted in Figure 15.

The water table rose slightly during snowmelt in Basins A and D. The rise in basin A occurred earlier than that in Basin D. Basin A drained rapidly after snowmelt but Basin D held more water and retained it longer than Basin A. The deep water in Basin D may have insulated the frozen ground beneath the wetland and slowed the rate of recession of the frost. The small amounts of surface water accumulated in Basins C and E did not appear to impact groundwater level.

Water quality data for these piezometers is shown in Table 4.

5.2.3 Personal Wells

Water samples obtained from personal wells and dugouts are also of poor quality for drinking water (Table 5). Well water samples are similar to results from piezometer sampling, with results exceeding drinking water quality guidelines for sulphate, iron, manganese, and hardness (returning values in excess of 2000 mg/L). Some dugout samples also exceed microbiological guidelines, including the presence of fecal coliforms.

5.3 Surface Water Quality

5.3.1 Runoff

Runoff in the basins at Elstow tends to temporarily pond. The basins are gently sloping, having slopes ranging from 0-2% No manure from the barn has been applied to these fields to date, and therefore data collected to date can be considered baseline data. However, it should be noted that the fields at Elstow may have had cattle present in the past and in the winter of 1999/2000, cattle were turned out in the field containing basins D and E for a period of 3 – 4 weeks.

The snowpack at Elstow during the winter of 2000-01 was less than in 1999-2000 and consequently less water accumulated in the basins. In Basin B, where the stubble burned in the fall, water did not accumulate at all. A single surface water sample was obtained from Basin C on March 20, 2001 while 3 samples were collected between March 20 and 30, 2001 from both Basin A and Basin E. Basin D accumulated more water than the other basins and contained water until April 23, 2001. A total of 8 surface water samples were taken from Basin D. Water quality data for the snowpack is given in Table 6 while the surface water quality data are summarized in Table 7.

Snowmelt runoff (Table 6) generally contained considerably more nutrients than were measured in the snowpack (Table 7) and reflects some degree of soil-meltwater interaction. The NO_3 concentrations measured in the runoff in 2001 were considerably higher than those measured in the previous year and may reflect the fall cultivation of the basins in 2000.

5.3.2 Surface Water

Surface water sample analysis of the existing water bodies indicates the variability in water quality that occurs from season to season (see Table 8). The extremely high fecal coliform count (41000 cts/100 mL) during fall 2000 in water body E can be attributed to the presence of cattle in the area at this time. Other fecal coliforms counts are likely accounted for by the presence of the wildlife in the area.

5.4 Soil Quality

The land surface at the Prairie Swine Centre Elstow site is defined as moderately rolling to undulating with glacial lacustrine-alluvial plains. Aerial photograph examination reveals a surface with many potholes, indicating poor surface drainage. The property is located on the Saskatchewan Rivers Plain physiographic region. Surficial soil is characterized as variable textured lacustrine and alluvial sands, silts and clays. The upper 30-40m of this site consists of glacial till and stratified drift. This is underlain by 30 to 50 m of the Bearpaw formation, which consists of non-calcareous silty clay shale. This is followed by 20-30 m of the Judith River Formation (non-calcareous sand, silt and clay) and 270 m of silty clay shale of the Lea Park Formation – Upper Colorado Group.

Soils at this site are classified as Dark Brown Chernozem of the Elstow association being moderate to fine textured. PFRA drill logs from the test holes (Appendix D) indicate approximately 100 - 250 mm of topsoil followed by medium to plastic clay to a depth of approximately 7 to 11 m below grade. This is underlain by glacial till to a depth of 31.5 m. An intermittent sand and gravel layer is present between 21 and 30 m depth. The moisture content of the upper clay is between 30 and 40%, with the till at around 15% (PFRA drill logs). Moisture content in the upper three meters range from approximately 25 to 43%, increasing slightly with depth (Table 9).

5.5 Tile Drain Monitoring

Due to the consistent nature of the measurements, in fall 2000 the decision was made to perform tile drain monitoring on a monthly basis. Tables 10 and 11 gives the results of the monitoring. Pipes were not always accessible due to barn construction and / or snow build up. No indications of seepage were noted.

6.0 Conclusions

A complete database that establishes baseline environmental quality as well as any changes of quality that have occurred during the early start-up of an intensive hog facility has been established for the Prairie Swine Centre Elstow Research Farm. All aspects of environmental concern surrounding the construction of commercial hog barns have been included: surface water, ground water, soil, and air quality.

Data gathered through this project indicate that information regarding the background quality of environmental parameters is important to establish for an environmental impact study. Parameters that are often used as indicators of livestock pollution (i.e. fecal coliforms in the surface water) may be present before the influence of the facility is felt.

It is now possible to consider PSC Elstow a fully characterized site, unique in the ability to support studies of true environmental impact of intensive swine operations.

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